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RADIO OBSERVATIONS OF USSR SATELLITE SHIPS

Yoshiaki NAKATA, Miyao KAN, Yasuharu ARIMA, Kazunori ARAKI

Radio Research Laboratories,

Ministry of Posts and Telecommunications, Tokyo, Japan

Contract No. AF62 (531)-1235

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MAY, 1963

Prepared
for

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
OFFICE OF AEROSPACE RESEARCH
UNITED STATES AIR FORCE
BEDFORD, MASSACHUSETTS

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CONTENTS

ABSTRACT

This report presents the results of the Doppler frequency shift having received the beacon signals and voices transmitted from the satellite ships which were launched in USSR.

1. Introduction

After Sputnik 3 was burnt out into the atmosphere on April 6, 1960, the Russian satellites have been launched as a series of satellite ships 1–5 and Vostoks 1, 2, 3 and 4, Cosmoses 4 and 7 as shown in Table 1. The recoveries of these ships have been successful except the satellite ships 1 and 3. Instead of 20.005 Mc of the transmitting frequency used in Sputniks 1–3, a new frequency of 19.995 Mc has been used as the telemetering or beacon frequency in the satellite ships and the frequency on 20.005 Mc has been used as voice communication of spaceman in Vostoks.

This final report of extended contract of the contract AF 62 (531)–1235 will present the analytical results of the Doppler frequency shift of the beacon signals transmitted from the USSR satellite ships shown in Table 1.

Table 1.

		Launched Date	Transmitted Frequencies (Mc)		Commencing Observation Rev. No.
Satellite Ship	1	1960 May 15	19.995		5
	2	Aug. 19	19.995		3
	3	Dec. 1	19.995		0
	4	1961 Mar. 9	19.995		0
	5	Mar. 25	19.995		0
Vostok	1	Apr. 12	9.019 20.006	19.995 143.635	not identify
	2	Aug. 6	15.765 20.005	19.995 143.635	0
	3	1962 Aug. 11	20.006	19.995	0
	4	Aug. 12	20.006	19.990	2
Cosmos	4	Apr. 24	19.995		2
	7	July 28	19.994		2

As these ships always circulated around the earth under the maximum electron density level of the ionosphere, we in Japan could easily receive these signals transmitted from the ships even since revolution number 0. Therefore we could fortunately observe the signals from the revolution number 0 for five cases as shown in Table 1.

2. Equipment

The receiving equipment system is almost same as reported already in Final Report of the "Satellite Tracking Project" under the original Contract AF 62

(531)–1235. Speaking briefly here, the receivers used are in a quite stable type, having crystals in the 1st and 2nd local oscillators and the beat oscillator, and the antenna system is a horizontal $\pi/2$ dipole placed in the east-west direction and at a height of $\pi/4$ above the grid reflector.

3. Observation of signal from satellite ship 1 (Sputnik 4)

A new Soviet's satellite whose transmitter was operated at a frequency of 19.995 Mc instead of 20.005 Mc used in Sputniks 1–3 was successfully in orbit on May 15, 1960. We observed its signal since revolution number 5. However we did not obviously notice the Doppler frequency shift until the revolution number 8 because of the weak signals in far passages. The first greatest value of the maximum Doppler frequency shift attained 10.4 c/s at revolution number 12. Thus, as shown in Fig. 1, the times of the nearest approach are plotted for each

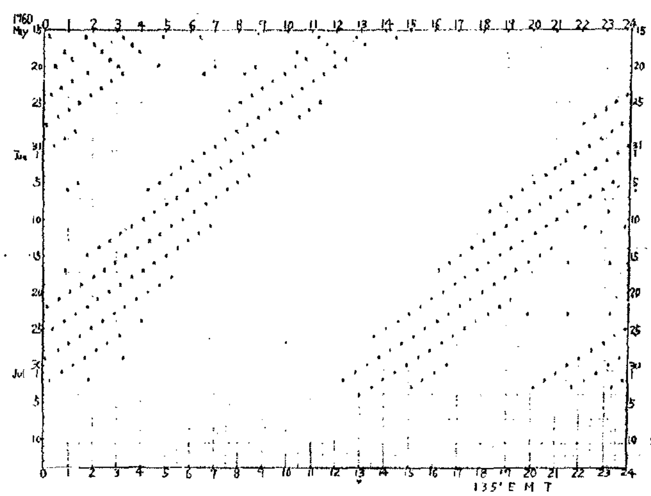

Fig. 1. Plots of nearest approach times on every day for satellite ship 1 (Sputnik 4).

passage every day. The rough times of the nearest approach on the following day could be predicted by extrapolating the time of nearest approach for the each passage group. However we noticed that on May 19, 1960, the observed times of nearest approach were abruptly delayed from the predicted times by about 2.5 and 6 minutes for the passages of revolution numbers 64 and 65 respectively. Then we supposed that some experiments such as a separation of the cabin from the satellite ship would have been done. In order to confirm and decide the revolution number at which the experiment had been made, we com-

pare the data with those on the following days. The differences between the observed times of nearest approach and the predicted times are plotted against the revolution number in Fig. 2. The curve shows that there is a discontinuity at the revolution number 63 and that the period of revolution becomes greater than before by about 3 minutes. The circumstance corresponding to this discontinuity is also seen on May 19, 1960 in Fig. 1. The change of the period can be easily illustrated in Fig. 3 obtained from our observational data.

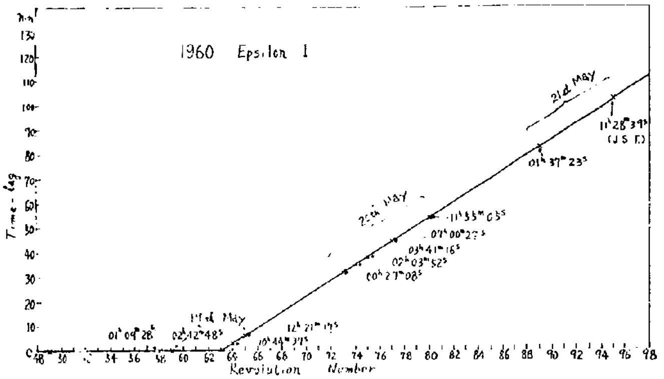

Fig. 2. The difference values of observed nearest approach time from predicted time against revolution number.

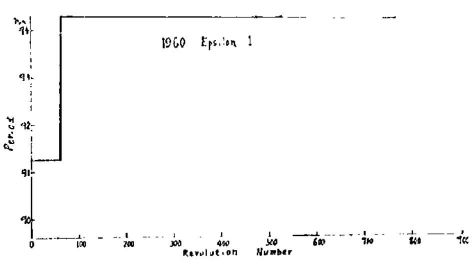

Fig. 3. Sudden change of the period of satellite ship I at the time of separation experiment of cabin from the ship.

we could afterwards receive the signal from Sputnik 4 for a long time for each passages. Then we indicate all traces of fade-in of original in a map for each passage. We could receive very often the signal from the American zone or European zone under the horizon. It is of interest that we could hear the strong signal on the revolution number 769 whose trace passed over Japan, following the weak signal in the trace from the longitude of 138°E to Alaska. On

the other hand, we received the following message from the Smithsonian Astronomical Observatory: "Information received from NSSCC indicates that the transmitter of 60 Epsilon 1 (19.995 Mc) has ceased transmitting somewhere between 769 and 775". Thus, combining our observational result with the above message, we conclude that the ceasing of the signal occurred at the last part of the revolution number 769.

4. Observation of signal from satellite ship 2 (Sputnik 5)

The second Russian satellite ship was launched on August 19, 1960. Its signal which was transmitted on the same frequency of 19.995 Mc as satellite ship 1 (Sputnik 4) could be strongly received since the revolution number 3 immediately after hearing an announcement of its launching. At this passage the Doppler effect was obviously present, but the time of nearest approach and its maximum rate of the Doppler frequency shift could not be decided due to the interference of another component of waves which would be reflected by the ionosphere.

According to the announcement from Moscow on the information of the former Sputnik 4, the ship and cabin would have been expected to be recovered to the earth at the same time. This means that if the recovery of ship was made successfully, the transmitted signal would have stopped. Considering from such a reason, we watched carefully the stop of the signal or the sudden change of the period of revolution accomanied by the experiment of recovery of the satellite.

Fig. 4 shows all traces of fade-in of the signal from Sputnik 5 in the map. The thick line corresponds to the received signal in the strong intensity and the thin line to the weak signal. We could receive clearly the signal for the revolution number 15 especially from the Western Siberia. Therefore we expected to receive the signal in the same manner for the revolution number 16. However we could nor receive even the weak signal, neither for the orbit of the revolution number 17 which was to pass near Japan.

Accordingly we come to conclusion that the experiment of recovery of ship was done during the former part of the revolution number 16. However it is reported by USSR that the success of the recovery of ship and cabin was made at the revolution number 17. It is wonder that there was the difference of revolution number between announcement by USSR and our observational result.

5. Observation of signal from satellite ship 3 (Sputnik 6)

The third Russian satellite ship (Sputnik 6) was launched on December 1, 1960. The signal which was transmitted from this ship was completely caught in our Brush record and magnetic tape from revolution number 0 until its vanishing into the atmosphere. From 07 *h* 27 *m* *Z*, as shown in Fig. 5, jamming signal was received in the receiver of 19.995 Mc and when its intensity became weak, the abrupt fade-in of telemetering signal from satellite ship 3 (Sputnik 6) happened to occur during careful watch of jamming signal. Accordingly, the map shown

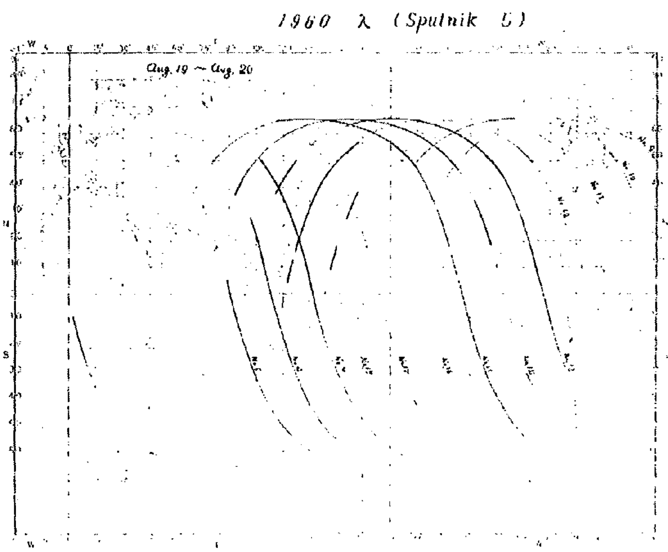

Fig. 4. The traces of location of the received signals of satellite ship 2 (Sputnik 5).

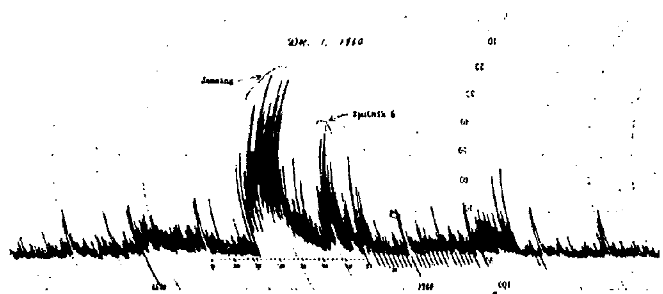

Fig. 5. Jamming signal at pre-launching of satellite ship 3 (Sputnik 6).

in Fig. 6 presents all traces of fade-in of the signal of satellite ship 3 fortunately from revolution number 0 for each passage. The signal in revolution number 0 is first found out at the place of latitude 65°N and longitude 125°E, as the locus is calculated and the time of fade-in of the signal is decided. It is the first time for us that from the Doppler effect in the signal the launching of a new satellite

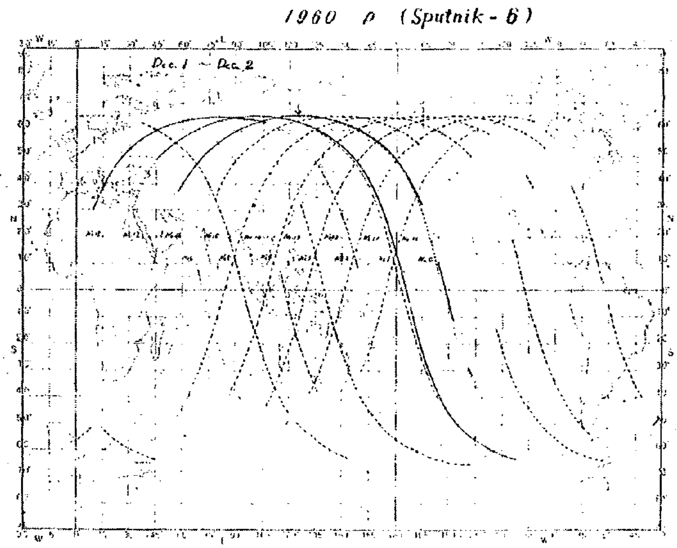

Fig. 6. The traces of location of the received signals of satellite ship 3 (Sputnik 6).

was noticed before an announcement of USSR. After this satellite ship was in orbit for about one day, its recovery to the earth was tried at the first state of revolution number 18 and the signal ceased transmitting at the point of latitude 62°N and longitude 105°E, which were decided by the calculated orbit and the time of cease of the signal at the time 10 *h* 20 *m* 11 *s* *Z*, December 2, 1960. It was reported that this ship was burnt up with animals aboard.

6. Observation of signal from satellite ship 4 (Sputnik 9)

Immediately after a signal was found out on March 9, 1961, and considered to be transmitted from a new satellite on a frequency of 19.995 Mc, the tape-recorder was operated for its signal. It was reported later that this satellite was the Russian satellite ship 4 (Sputnik 9). Unfortunately as it was late to perceive the signal, the Doppler curve is only obtained for the last part of passage after the nearest approach. The passage is considered to be revolution number 0. The signal on next orbit was hardly listened because the signal skipped out from the ionosphere. Thus the recovery seemed to be done at the first stage of revolution number 2.

7. Observation of signal from satellite ship 5 (Sputnik 10)

The dotted signal suggesting telemetering code was heard on monitoring the

frequency of 19.995 Mc for some intervals from the time of 06 *h* 08 *m* *Z* on March 25, 1961. A Doppler frequency shift was obviously perceived. A result of analysis of Doppler frequency shift showed launching of a new satellite before announcement of USSR. A maximum frequency shift gives 1.3 cycle per second at the time of nearest approach on 06 *h* 12 *m* 12 *s* *Z* for this passage. For the second orbit the weak intensity of the signal having Doppler effect was also perceived. However, for the third orbit which should have passed through near Japan, signals have never been listened. Thus it was presumed that the recovery of the ship was done at the first stage of third orbit. Although the frequency used in satellite ships 4 and 5 was not announced officially, the use of frequency of 19.995 Mc was confirmed by our observations.

As mentioned above, it was fortunate that observations of revolution number 0 had been done for satellite ships 3, 4 and 5. We believe that these owe to our great efforts continued for a long time. Comparing these signals with those of the satellite ships 1 and 2, it is noticed that there is very definite difference in intermittent interval of telemetering. It is seems that telemetering of the latter group was simpler than that of former group.

8. Observation of signal from Vostok 1

The first man-satellite ship in the world was launched in USSR on April 6, 1961. According to the announcement of USSR, the frequencies used in the ship were 9.019, 19.995, 20.006 and 143.625 Mc as shown in Table 1. At this time we were operating tape-recorder for the signals on frequencies of 19.995 and 20.006 Mc. However by play-back of tapes we could not obtain any signals from the satellite. From our experiences of receiving of signals from the satellite ships 3, 4 and 5 and later Vostoks 2 and 3, we could surely catch the signals at the first orbit if the signal was transmitted in the usual intensity. Thus the signals would not be transmitted at the frequencies of 20.006 and 19.995 Mc, or signals would be too weak to be caught by a reason which will be noted in the following section.

9. Observation of signal from Vostok 2

Vostok 2 was launched on August 6, 1961 and returned successfully to the earth after running round the earth more than 17 times. We could completely catch the signals of 19.995 Mc and 20.006 Mc transmitted from Vostok 2 from the first orbit throughout its all flights, because tape-recorders by AM and beat frequency receiving methods had been operated for these frequencies from its prelaunching. Therefore it was found that the wave of 19.995 Mc was transmitted continuously and 20.006 Mc intermittently. And as we continued to operate the tape-recorder until recovery was done, the traces of fade-in of signals could be obtained in detail on the map for each orbit by the playback of tapes. Fig. 7 indicates that the broken lines give weak signals and full lines strong signals for 19.995 Mc, and that round marks give the places where Major Titov called for the ground base station by the frequency of 20.006 Mc. Furthermore it is seen that the time interval of fade-in of signals is longer in the northern hemisphere than

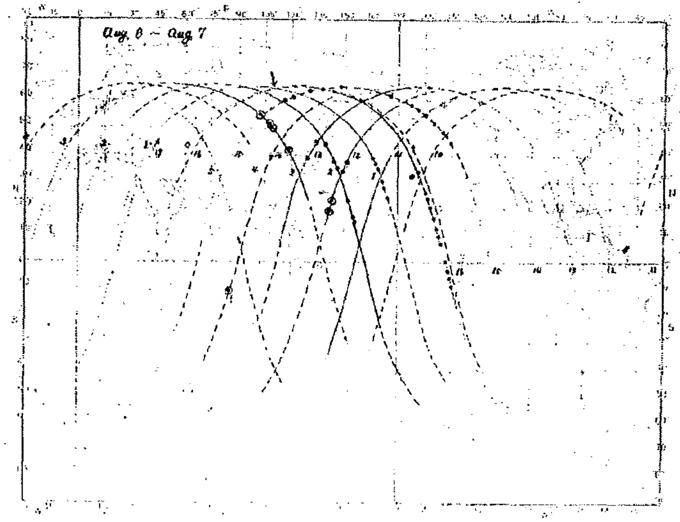

Fig. 7. The traces of location of the received signals of Vostok 2.

in the southern hemisphere. This is attributed to the evidence that the maximum electron density in the northern hemisphere is larger than in the southern hemisphere, because the signal from Vostok 2 circulated always under the maximum electron density level of the ionosphere and did hardly skip out in the nothern hemisphe-e. It is also interesting that the signal of 19.995 Mc on the first orbit comes to fade in abruptly at a place of latitude 64°N and longitude 110°E as given by an arrow mark in the map. This same manner was experienced on the case of Sputnik 6 (satellite ship 3) launched in December 1, 1960. This means that the sudden fade-in of signals was caused by a first transmitting of waves because of opening of antenna which was closed in the rocket until in orbit. Considering the sudden fade-in of signals in the first orbit such as Vostok 2 and satellite ship 3, failure to observe the telemetering signal and voice of Major Gargarin in Vostok 1 on April 12, 1961 would be attributed to a closed antenna, considering of our operation of tape-recorder for these waves at his flight. Returning to Major Titov, his first voice was announced by Russian language from the point of latitude 35°N and longitude 170°W which is shown by the round mark on the first orbit in the map. We believe that his voice listened by us at the time of 06 h 25 m was first in the world outside the Soviet Russian domain. Add also in the second and third orbit, his voices were emitted above the Pacific Ocean. These voices calling for the Wesna station 2 on the ground are indicated by signal round mark in the map. However, on the fourth orbit, Titov spoke for the Wesna station 3 as the places of calling are indicated by double

round mark. As seen from the single and double round marks on each orbit, these are divided into two groups, that is, the single marks lie on the area having the center in Kamchatka and the double marks roughly on the area having the center in Inner Mongolia. It is interesting that no voice was heard on each orbit on the main land of Russia although the signals of 19.995 Mc should have been definitely received.

On the other hand, there is a question if the voices obtained would be transmitted from the satellite or they might be from airplane. Expecting this question, our receiving equipments were operated on that day by both AM detection and beat receiving methods in order that the former receives a clear voice and the other gets Doppler frequencies of 19.995 Mc and 20.006 Mc. Signals of 19.995 Mc were transmitted continuously from the satellite so that the fine continuous deviation of the frequency shift caused by the Doppler effect is obtained as shown in Figure 8. However, as the voice was intermittently announced in a short

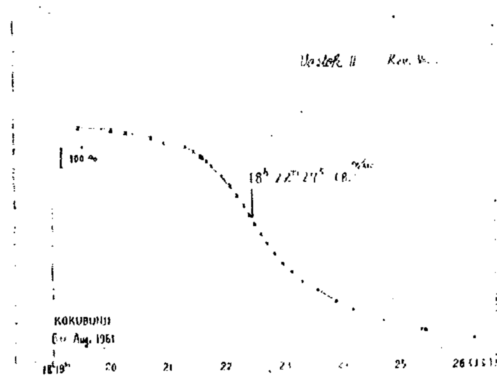

Fig. 8. Doppler frequency curve on revolution number 2 of Vostok 2.

time and its frequency spectrum contains many harmonics, the Doppler effect in a series of voices could not be identified. Accordingly, to investigate the Doppler effect in series of voices intermittently transmitted on some orbit (for example the third orbit), the vibralizer (sona-gram) was used for voices containing the Doppler frequency shift which occurred in carrier frequency. Fig. 9 (a) gives the spectrum of voice alone, but Figs. 9 (b)-(d) give the shifts of carrier frequency in the voice spectrum which decrease in frequency in lapse of time. As frequencies of 19.995 and 20.006 Mc are close in the frequency, the Doppler frequency shift should be similar. When the shifts of carrier frequency of the intermittent voice are plotted into the Doppler curve of 19.995 Mc as shown in Fig. 8, it is found that the points of frequency shift of 20.006 Mc lie on the Doppler curve of 19.995 Mc. Thus it is concluded that the voice and telemetering signals were transmitted from the same satellite.

Fig. 9 (a). Spectrum of frequency of the voice signal of Vostok 2 obtained by AM receiver.

Fig. 9 (b)–(d). Spectrum of frequency of the voice signal of Vostok 2 obtained by beat receiver.

10. Observation of signals from Vostoks 3 and 4

Cosmoses 4 and 7 among cosmos series were satellite ships. It was difficult to get an accurate Doppler frequency shift of their signals, because the frequency of signals transmitted from these ships fluctuated due to keying of space and mark of telemetering.

After about one year since Vostok 2 was recovered Vostok 3 was launched on Aug. 11, 1962 and Vostok 4 on Aug. 12, 1962. Both spacecraft were in close orbit planes. Also in the case of launching of Vostok 3, we could obtain the signal at a frequency of 19.995 Mc since revolution number 0, but we could not receive the voice although monitoring of 19.995 Mc and 20.006 Mc. Thus the voice was not transmitted at the first orbit but we could hear the voice at the second orbit.

For Vostok 4 we caught the signal at a frequency of 19.990 Mc since revolution number 2 (the third orbit). We used the Doppler effect to follow the signals transmitted in each spacecraft's tracking beacon.

For a while after the launching of Vostok 4 was reported, Japan is fortunately situated in good place to know the distance between both ships of Vostok 4 at revolution number 2 and Vostok 3 in its revolution number 18, because both spacecraft flew from north-east to south-east across Hokkaido Island, Japan. At nearest approach times of them for our station, spacecraft were at angles of 13° degrees for Vostok 3 and 22° degrees for Vostok 4 above the horizon. From

the time lag of nearest approach time, Vostok 3 tailed Vostok 4 by about 120 km, and distance between two orbits was about 250 km. This value becomes a little larger compared with the reported orbital element. The error is due to the dispersive Doppler curves. As given in Fig. 10 a tracking plot of separation of

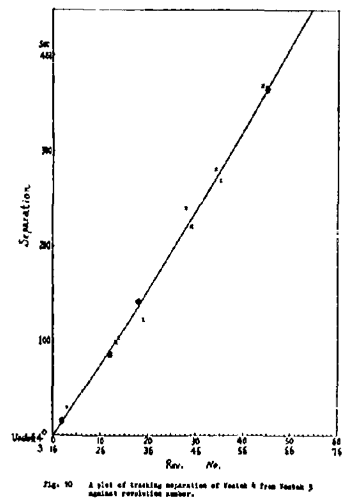

Fig. 10. A plot of tracking separation of Vostok 4 from Vostok 3 against revolution number.

Vostok 4 from Vostok 3 against revolution number indicates a steady progression and the time lag between them at our last observatien was a little more than 6 minutes. Then, there is an increase of the time lag of 7 seconds per one revolution. Extrapolating backward the line of the time lag from its tracking data in the figure we found that there is no time lag at revolution number 0, that is, both vehicles came nearest each other at approximately latitude 65°N in the first crossing of the two orbits. At the time of their recoveries, both ships stopped transmitting the signals with the time of about 6 minutes by an imagined reason that their antennas were burnt up in the atmosphere. This time lag of 6 minutes at our last observation corresponds to the time difference reported by the Soviet in the landing of two ships on August 15, 1962.

11. Conclusion

We have shown that, based upon observations of several Soviet man satellite vehicles, it has been possible to establish the launching of any transmitting orbital

vehicle from the USSR. By means of Doppler measurements it has been possible to plot the ephemeris of these satellites from launch to re-entry. It has been possible to measure the separation in orbit as a function of time, and to infer the difference between landing times of Vostok 3 and Vostok 4.

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